איגוד ישראלי לבקרה אוטומטית

IAAC^3

IAAC Control Conference

– Back to life in control – חוזרים לחיים מבוקרים

to celebrate that we can finally, after more than a year,
listen to each other in person

- Book of Abstracts -

Organizer:

- Per-Olof Gutman, Technion

Sponsors:

- Bernard M. Gordon Center for System Engineering at the Technion
- Technion – Israel Institute of Technology
- Faculty of Mechanical Engineering, Technion

Official wine purveyor:

- VITKIN WINERY ~ יקב ויתקין

Shirley and Manny Ravet Auditorium 6

D. Dan and Betty Kahn Mechanical Engineering Building, Technion–IIT

Monday, 5 July 2021

Welcome

During the miserable corona year, IAAC refrained from organizing events (except GSC for students), since it was painfully felt that the Zoom or hybrid formats were not suitable. Now, when larger gatherings are allowed, we are going to celebrate!

At IAAC³ we are happy to present some academic and industrial research **performed during the corona year**. There are 18 attractive presentations in four sessions covering Controller Synthesis, Applications, Systems Theory, and Navigation/Estimation. Hopefully, everyone will find something of particular interest, and also unexpected gems that pique the curiosity.

Most importantly, however, is to meet old and new friends and colleagues for fruitful discussions after the dry corona year. To reach this goal, please come in multitudes, and please help us publicize this event by sending this Invitation to relevant researchers, engineers, and students who may not be on our mailing list.

Looking forward to seeing you all at IAAC³!

Per-Olof Gutman IAAC³ Organizer
Leonid Mirkin IAAC President

Program

8:15	Gathering
8:50	Opening
9:00	**Oded Yaniv** (Gevasol), **Stanimir Mollov** (MOOG) *Synthesizing all filtered PI/PID controllers satisfying gain, phase & sensitivity specifications*
9:20	**Pedro Mercader** (Nordex), **Daniel Rubin** (GM), **Hoai-Nam Nguyen** (IFP Energies Nouvelles), **Alberto Bemporad** (IMT Lucca), **Per-Olof Gutman** (Technion) *Interpolation-based predictive control*
9:40	**Adrian-Mihail Stoica** (P Bucharest), **Isaac Yaesh** (Elbit) *Static output feedback revisited*
10:00	**Patrizio Colaneri**, **Gian Paolo Incremona** (P Milano), **Leonid Mirkin** (Technion) *Internal model for state feedback revisited*
10:20	**Marco Fabris**, **Daniel Zelazo** (Technion) *Secure consensus via objective coding: robustness analysis to channel tampering*
10:40	Coffee / tea break
11:10	**Izhak Bucher**, **Nir Ben-Shaya** (Technion), **Amit Dolev** (EPFL) *Auto-resonance control of a nonlinear, parametrically excited system*
11:30	**Yarden Sharon** (BGU), **Daniel Naftalovich** (Caltech), **Yael Refaely** (Soroka MC), **Ilana Nisky** (BGU) *Adaptation to time-dependent perturbations in robot-assisted surgery training*
11:50	**Maxim Kristalny** (Rafael), **Jang Ho Cho** (KIMM) *On the topology of interaction control with force and velocity measurements*
12:10	**Yossi Ben-Asher**, **Elon Rimon** (Technion) *Time-optimal trajectories for a car-like mobile robot*
12:30	Lunch break (Students Gallery)
13:50	**Eduard Eitelberg** (Ort Braude) *Population and wealth age distribution dynamics*
14:10	**Daniel Alpay** (Chapman U), **Izchak Lewkowicz** (BGU) *Quantitatively hyper-positive real functions*
14:30	**Daniel Zelazo** (Technion), **Xudong Chen** (U Colorado), **M. Ali Belabbas** (UIUC) *On structural rank and network resilience*

Program

14:50	**Arkady Lichtsinder** (Rafael), **Per-Olof Gutman** (Technion), **Yaron Zimmerman** (Spectrum Eng), **Pedro Mercader** (Nordex), **David Yehuda**, **Sagi Ben-David** (Applied Materials) *A computationally reliable stick-slip friction model with pre-sliding effect*
15:10	**Izchak Lewkowicz** (BGU) *Realizations of continuous/discrete positive/bounded-real systems are interrelated*
15:30	Coffee / tea break
16:00	**Ron Teichner**, **Ron Meir** (Technion) *Discrete-time Kalman filter error bounds in the presence of misspecified measurements*
16:20	**Daniel Rubin** (GM), **Per-Olof Gutman** (Technion) *Vision based estimation of vehicle states*
16:40	**Martin Weiss**, **Vitaly Shalumov**, **Tal Shima** (Technion) *Optimal pursuit guidance with delayed engagement decisions*
17:00	**Barak Pinkovich** (Technion), **Boaz Matalon** (Rafael), **Ehud Rivlin** (Technion), **Héctor P. Rotstein** (Rafael) *From parking to landing (and other aerial exploration problems)*
17:20	Closing

Abstracts (morning)

9:00 **Oded Yaniv** (Gevasol), **Stanimir Mollov** (MOOG)
Synthesizing all filtered PI/PID controllers satisfying gain, phase & sensitivity specifications

Abstract: The majority of industrial control architectures are filtered PI, PD, PID or cascaded with up to three sensors. Is it possible to design all relevant controllers that satisfy margin specifications without user intervention or experience? The answer is yes, and such an algorithm is presented here. The algorithm solves sets of two linear equations and a single polynomial equation.

The result is a fully automated design sequence calculating all filtered PI/PD/PID controllers with an a priori chosen filter architecture that fits the industry needs, which are that a) the design specifies phase and gain margins, and bounds the sensitivity or complementary sensitivity function, b) it accounts for the exact amount of plant uncertainty (without over-estimating the uncertainty and the resulting over-design), c) it provides explicit equations to determine the set of all possible controllers, d) it can be applied to plants of any order, including ones with pure delay, unstable, and plants given by measured data, e) it allows for different sensor models for the P, I and D terms, f) it is possible to extend the method to account for sensitivity specifications that depend on the frequency, g) in using explicit equations, the algorithm is very fast, h) applying the algorithm does not require any control background to locate the optimal low-pass filter; extra conditions are required for the extension to PID and cascaded controllers.

9:20 **Pedro Mercader** (Nordex), **Daniel Rubin** (GM), **Hoai-Nam Nguyen** (IFP Energies Nouvelles), **Alberto Bemporad** (IMT Lucca), **Per-Olof Gutman** (Technion)
Interpolation-based predictive control

Abstract:

- Rubin, Daniel, Pedro Mercader, Per-Olof Gutman, Hoai-Nam Nguyen, and Alberto Bemporad. "Interpolation based predictive control by ellipsoidal invariant sets." IFAC Journal of Systems and Control 12 (2020): 100084.
- Mercader, Pedro, Daniel Rubin, Hoai-Nam Nguyen, Alberto Bemporad, and Per-Olof Gutman. "Simple interpolating control." ROCOND-2018, IFAC-PapersOnLine 51, no. 25 (2018): 42-47.
- Nguyen, Hoai-Nam. "Constrained control of uncertain, time-varying, discrete-time systems." Lecture Notes in Control and Infomration Sciences 451 (2014): 17. Ph.D. precursor downloadable at https://tel.archives-ouvertes.fr/tel-00783829/document

9:40 **Adrian-Mihail Stoica** (P Bucharest), **Isaac Yaesh** (Elbit)
Static output feedback revisited

Abstract: The synthesis problem of static output feedback controllers in an anisotropic norm setup is considered. The anisotropic norm setup is a stochastic one, and it leads to an intermediate topology between H_2 and H_∞. A tractable synthesis approach under this setup, involving iterations over a convex optimization scheme is suggested. The resulting synthesis method is then applied to a simple flight control problem.

10:00 **Patrizio Colaneri**, **Gian Paolo Incremona** (P Milano), **Leonid Mirkin** (Technion)
Internal model for state feedback revisited

Abstract: A standard way to incorporate an internal model into state-feedback design is to augment the plant by the dynamics of the model and to design the feedback gain for the resulted augmented system. An obvious disadvantage of this approach is an increase of problem dimension, which is especially restrictive for infinite-dimensional models, like those arising in repetitive control. We propose an alternative approach, in which special dynamics are added to the loop to compensate for the addition of the internal model. The design problem reduces then to a standard state-feedback design for the original plant, with no internal model dynamics. As an attractive byproduct, the modeled part is completely eliminated from the load disturbance in the equivalent design.

10:20 **Marco Fabris**, **Daniel Zelazo** (Technion)
Secure consensus via objective coding: robustness analysis to channel tampering

Abstract: The consensus protocol has become a canonical model for the study of multi-agent systems (MASs). Recently, the increasing demand for safety and security measures in the most advanced technologies has skyrocketed in many fields, including that of MASs. In fact, the concerns about protection of networked systems from cyber-physical attacks are not new, and have attracted a fair amount of attention in the engineering community due to high-profile incidents. As a consequence, several approaches to improve the security of such systems or understand their vulnerabilities have been developed. This presentation mainly addresses continuous-time multi-agent consensus networks where an adverse attacker affects the convergence performances of said protocol. In particular, we develop a novel secure-by-design approach in which the presence of a network manager monitors the system and broadcasts encrypted tasks (intended as hidden edge weight assignments) to the agents involved. Each agent is then expected to decode the received codeword containing data on the task through appropriate decoding functions by leveraging advanced security principles, such as objective coding and information localization. Within this framework, a stability analysis is conducted for showing the robustness to channel tampering in the scenario where part of the codeword corresponding to a single link in the system is corrupted. A trade-off between objective coding capability and network robustness is also pointed out. Lastly, numerical simulations are given to validate the theoretical results.

11:10 **Izhak Bucher**, **Nir Ben-Shaya** (Technion), **Amit Dolev** (EPFL)
Auto-resonance control of a nonlinear, parametrically excited system

Abstract: A closed-loop control scheme of a parametrically excited nonlinear structure is described. By controlling the relative phase, the open-loop unstable, non-unique solution branches, are stabilized under a 2:1 excitation. The closed-loop automatically locks onto any desired point on the solution branches exploiting the uniqueness of phase values. The method is utilized to actuate axially driven slender beams, representing a nanowire-based sensor. Automatic excitation is carried out by a relay-based Autoresonance scheme fed by automatic gain control and a tunable phase shifter. By inducing parametric excitation, the nonlinear response is exploited to obtain high sensitivity to small changes in potential forces (e.g. Van der Waals) and thus enabling the detection of minute topographic features. Operating in closed-loop paves the way to stable operation of such sensors and to choosing the optimal operating point. Some unique features of the controlled nonlinear system under pumping are illuminated. The paper briefly outlines the mathematical model, asymptotic analysis, numerical simulations and large-scale experiments, all validate the proposed method.

11:30 **Yarden Sharon** (BGU), **Daniel Naftalovich** (Caltech), **Yael Refaely** (Soroka MC), **Ilana Nisky** (BGU)
Adaptation to time-dependent perturbations in robot-assisted surgery training

Abstract: In robot-assisted minimally invasive surgery (RAMIS) surgeons use robotic manipulators to control the movements of instruments, which are inserted into patients' bodies via small incisions. RAMIS offers many advantages over open surgery. However, to reap the benefits of RAMIS, surgeons must be well trained to use the robotic systems. We designed an experiment to investigate the effect of time-dependent perturbations on the learning of a surgical task. In our experiment, the participants completed a pattern-cutting task using the da Vinci Research Kit. In this task, the participants used scissors to cut a circle drawn on a non-woven gauze while they were exposed to force perturbations that alternatingly pushed their hands inwards and outwards in the radial direction. We hypothesized that the motor system would adjust motor commands and reduce error with training. If surgeons do manage to improve performances during exposure to the perturbations, it is interesting to understand the learning mechanisms behind the improvement, and it is important to test whether this learning impairs their ability to cope with other conditions.Thirty participants took part in the experiment: (1) a control group that trained without perturbations, and (2) a 1Hz group that trained with 1Hz periodic force perturbations. We monitored their learning using metrics that quantified task performance, and metrics that allowed us to follow different approaches of the participants. We found that participants in the 1Hz group learned how to cope with the perturbations and improved their performances during training but did not adapt to the perturbations – we did not observe aftereffects of adaptation. Our results lead the way toward developing training protocols that will incorporate time-dependent perturbations, and make an important behavioral step toward understanding motor learning in real life tasks.

11:50	**Maxim Kristalny** (Rafael), **Jang Ho Cho** (KIMM) *On the topology of interaction control with force and velocity measurements*
	Abstract: Increasing demand in robotic systems that interact with unknown environment and human operators raises a challenging class of interaction control problems. Problems of this kind are relevant in the areas of assistive and rehabilitation robotics, cooperative robotics, teleoperation, etc. Unlike classical control problems, where the goals are command tracking and/or disturbance rejection, interaction control aims at modifying system dynamics making it more appropriate and safe for the interaction. In particular, this requires to maintain stability both in free motion (nominal stability) and in contact with a largely varying environment dynamics (coupled stability). Most of works on interaction control focus on fixed control structures such as admittance and impedance control. In this work, we try to escape this "structure-oriented" paradigm and study the basic topology of the problem. Adopting the concept of Youla-based 2DOF control, we reveal a generic control architecture that splits the problem into two independent parts: nominal admittance shaping and disturbance rejection. As a by-product, a complete and compact parameterization of all achievable admittances is derived. The potential of the proposed architecture for analysis and controller design is demonstrated and validated experimentally.
12:10	**Yossi Ben-Asher**, **Elon Rimon** (Technion) *Time-optimal trajectories for a car-like mobile robot*
	Abstract: We study the time optimal trajectories of a car-like mobile robot navigating in an obstacle free planar environment. The robot, with forward and backward speeds, is modelled as a full car, with front and rear wheels. It is controlled by bounded acceleration of the front wheels, and by limited front-wheels steering rate. The problem is analysed as an optimal control problem, using the Minimum Principle with hard constraints on the controls. The problem is shown to possess a singular control part that can be obtained in closed form.

Abstracts (afternoon)

13:50 **Eduard Eitelberg** (Ort Braude)
Population and wealth age distribution dynamics

Abstract: Thomas Piketty presents a long-term quantitative analysis of the distribution of wealth in his book "Capital in the twenty-first century", first published in French in 2013. On p. 2, he writes: "Intellectual and political debate about the distribution of wealth has long been based on an abundance of prejudice and paucity of fact." Piketty fills the paucity with truly impressive quantity of fact. However, apart from a few simple algebraic equations, he does not present any mathematical model to explain the documented transients in the distribution of wealth in his book. He insists that "… to progress in our understanding of the historical dynamics of the wealth distribution and the structure of social classes, we must obviously take a pragmatic approach and avail ourselves of the methods of historians, sociologists, and political scientists as well as economists." [*ibid*. p. 33]

I take a thermodynamic (conservation of quantities) point of view and present a simple mathematical model to describe some of the macro-economic transients and cycles. It was the COVID19 epidemy, nay the sensationalised reporting of this epidemy, that led me to discovering an important connection between wealth and population dynamics (see also 'population pyramid'). With hindsight, it is so obvious: wealth is owned by the aging and dying population – wealth 'ages' together with its owners. I start with the following interacting partial differential equations for the population and wealth age density functions of time t and age z – $p(t,z)$ and $w(t,z)$ respectively:

$$\frac{\partial p(t,z)}{\partial t} = -\frac{\partial p(t,z)}{\partial z} + \dot{p}_{\text{migration}} - \dot{p}_{\text{death}}; \quad \frac{\partial w(t,z)}{\partial t} = -\frac{\partial w(t,z)}{\partial z} + \dot{w}_{\text{transfer}} + \dot{w}_{\text{creation}}$$

Additional algebraic and integral equations are added to define the terms in these differential equations, their boundary conditions and distributed feedback 'loops'.

14:10 **Daniel Alpay** (Chapman U), **Izchak Lewkowicz** (BGU)
Quantitatively hyper-positive real functions

Abstract: Hyper-positive real, matrix-valued, rational functions are associated with absolute stability (the Lurie problem). Here, quantitative subsets of Hyper-positive functions, related through nested inclusions, are introduced. Structurally, this family of functions turns out to be matrix-convex and closed under inversion.

A state-space characterization of these functions through a corresponding Kalman–Yakubovich–Popov Lemma, is given. Technically, the classical Linear Matrix Inclusions, associated with passive systems, are here substituted by Quadratic Matrix Inclusions.

14:30 **Daniel Zelazo** (Technion), **Xudong Chen** (U Colorado), **M. Ali Belabbas** (UIUC)
On structural rank and network resilience

Abstract: In this talk we introduce and explore the notion of structural rank of a matrix. We consider matrices defined by their structural zero/non-zero pattern and aim to understand how many non-zero entries can be changed to zero entries before the rank of the matrix drops. This value we term the rank-resilience of a matrix. We show that the rank-resilience of a matrix can be determined by solving a network max-flow problem on an associated bipartite graph derived from the matrix under investigation. The rank-resilience of a matrix turns out to be a good measure for the resilience of many multi-agent control systems where the underlying information exchange network may be susceptible to attack, and we demonstrate this with a simple example.

14:50 **Arkady Lichtsinder** (Rafael), **Per-Olof Gutman** (Technion), **Yaron Zimmerman** (Spectrum Eng), **Pedro Mercader** (Nordex), **David Yehuda**, **Sagi Ben-David** (Applied Materials)
A computationally reliable stick-slip friction model with pre-sliding effect

Abstract: Friction has strong influence on both the behavior and performance of a control system. Most of the conventional friction models exhibiting stick-slip behavior with pre-sliding are smooth, continuous ones, e.g., LuGre, Datkowicz, Dahl. These models use continuous analytical expressions to approach the primordial discontinuous physical process induced by friction. Thus, the same expression should be valid for both slip and stick modes. Such descriptions have usually an artificial nature and are based on non-physical parametrization.

The model proposed in this study is directly based on event-driven logic in order to conditionally separate between different friction modes. Such an approach makes it possible to parametrize, in a straight-forward way, essentially different modes of the surface interactions: stick mode with elastic deformation and sliding mode under dry and mixed lubrication conditions.

The central ideas are
(i) to introduce an additional state variable – "elastic deformation", and
(ii) to pre-define the initial deformation level such that the elastic force is equal to the last friction value preceding the stick, every time the stick mode starts.

Such a condition properly reflects the micro-elastic friction nature and provides smooth model performance.

Theoretical analysis in the frequency domain based on describing functions and simulation results are presented as well as experimental measurements verifying the proposed approach.

15:10 **Izchak Lewkowicz** (BGU)
Realizations of continuous/discrete positive/bounded-real systems are interrelated

Abstract: Although passivity is essentially a physical property, linear time-invariant *passive* systems can be characterized through their structure. We here first recall the rational functions version of it.

Then we show that the four variants of passive systems, positive/bounded continuous/discrete-time, are inter-related: Starting from a state space realization of one of the four, any other of the remaining three can be directly obtained, through a prescribed linear fractional transformation.

16:00 **Ron Teichner**, **Ron Meir** (Technion)
Discrete-time Kalman filter error bounds in the presence of misspecified measurements

Abstract: The performance of a discrete time Kalman filter in the presence of a misspecified measurement equation is considered. Analytical and easily calculable numerical bounds for the increment in filtering error energy are provided in an adversarial setting by formulating a high-dimensional optimization problem which is solvable via its Lagrange dual, a scalar convex optimization problem. The performance bounds are obtained for finite and infinite horizons.

16:20 **Daniel Rubin** (GM), **Per-Olof Gutman** (Technion)
Vision based estimation of vehicle states

Abstract: Advanced automated driving systems are under development, and accepted to hit the markets in a few years. These systems require more accurate knowledge of the vehicle states, and in particular the side-slip and road banking angle, which are practically unmeasurable.

We present a side-slip and roll angle observer which is aimed for such vehicle motion control. The observer uses data available from a front-facing camera and a few standard sensors, on-board any modern vehicle. The observer uses a kinematic model to design a multi-rate Kalman Filter. The designed observer is able to estimate the vehicle side-slip as well as its roll angle accurately. The results are verified in CarSim simulations and found to be superior to a benchmark vision-based observer, and to be suitable for closed-loop implementation. The estimator is shown to preserve closed-loop stability obtained with a state-feedback compensator.

16:40 **Martin Weiss**, **Vitaly Shalumov**, **Tal Shima** (Technion)
Optimal pursuit guidance with delayed engagement decisions

Abstract: We propose a guidance algorithm for a pursuer in a many-on-many intercept scenario, that includes the possibility of dynamic weapon-target (re)assignment based on a simple target priority scheme. Given the probabilities of success of each preceding pursuer against each possible evading target, a guidance algorithm is designed that provides minimum average quadratic effort over all the possible outcomes of the engagements that may take place during the time of flight. The guidance algorithm is derived using a linear(ized) engagement model and takes the form of a linear combination of (Augmented) Proportional Navigation guidance terms, which makes it readily implementable on conventional guidance systems. An efficient algorithm for the implementation of the guidance law is presented and numerical simulations based on the nonlinear equations of motion are used to demonstrate its performance.

17:00 **Barak Pinkovich** (Technion), **Boaz Matalon** (Rafael), **Ehud Rivlin** (Technion), **Héctor P. Rotstein** (Rafael)
From parking to landing (and other aerial exploration problems)

Abstract: In this talk we will discuss the problem of finding an appropriate landing spot for a drone in a dense urban environment. The approach considered here is *multi-resolution* in the sense that information is collected by a visual sensor at decreasing altitudes so that spatial resolution increases monotonically. It is also probabilistic in the sense that the objective is to find a region suitable for landing with a confident level larger than some pre-defined threshold.

One of the approach's main building blocks is a semantic segmentation algorithm that attaches probabilities to each pixel of a single view. The decision algorithm combines these probabilities with *a priori* data and previous measurements to obtain the best estimates. The feasibility of the approach will be illustrated by means of examples generated by a realistic close-loop simulator. We will also discuss how the formulation can be modified to solve other relevant exploration problems.